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Artificial light reduces elasmobranch bycatch in gillnets across multiple wavelengths and taxonomic groups

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ABSTRACT

Globally, the incidental capture of non-target species (bycatch) in fisheries has been linked to declines of ecologically, economically, and culturally important marine species. Coastal gillnet fisheries often incur high bycatch, necessitating the development of new bycatch reduction solutions. Net illumination is an emerging conservation technology that has successfully reduced sea turtle and other marine megafauna bycatch while maintaining target fish catch across multiple coastal gillnet fisheries. However, little research has been conducted to understand how elasmobranchs and bony fish respond to net illumination, particularly across taxonomic groups and orders. Moreover, most studies have used green LED lights, limiting our understanding of how net illumination performs across different wavelengths and light types. Here, we use a 7-year dataset to provide the first assessment on the effects of illuminating gillnets using four types of artificial light (i.e., green LEDs, green glowsticks, ultraviolet LEDs, and orange LEDs) on a diverse array of bony fish and elasmobranchs in Mexico's Gulf of California. We found that net illumination by all light types significantly reduced elasmobranch catch across several orders, with orange lights resulting in the greatest overall reduction. By contrast, net illumination had no significant effect on aggregate bony fish catch across all light types. Our results demonstrate that net illumination can reduce catch rates of a diverse array of elasmobranchs while revealing taxonomic-specific responses between bony and cartilaginous fishes, establishing the most comprehensive evidence to date of taxon- and wavelength-specific effects of this emerging bycatch reduction technology on fishes.

1. Introduction

Globally, fishing is an essential industry that supports economies and livelihoods, provides cultural identity, and creates food security (FAO, 2022). Gillnets are an important type of fishing gear, contributing a large share of small-scale fisheries catch and accounting for around 10% of the world's total fish landings (Cashion et al., 2018; He et al., 2021). However, coastal gillnet fisheries can have high incidental catch of non-target species (i.e., bycatch; Davies et al., 2009; Lewison et al., 2004; Lively and McKenzie, 2023; Northridge et al., 2017; Shester and Micheli, 2011), leading to declines or slowing population recovery in large marine species, such as sea turtles, marine mammals, and seabirds (Gilman et al., 2008; Majluf et al., 2002; Oliver et al., 2015; Peckham et al., 2007; Read et al., 2006; Dulvy et al., 2024). Bycatch also negatively impacts fishers due to lower target catch rates, damaged gear and increased repair costs, reduced operational efficiency, safety risks, and increased fishery regulations (Panagopoulou et al., 2017; Senko et al., 2014b; Gibbs et al., 2025; Suazo et al., 2024; Virgili et al., 2024). For example, a fishery closure due to loggerhead turtle bycatch in Baja California Sur, Mexico resulted in the loss of important seasonal income for fishers and their families (Senko et al., 2017). Therefore, developing bycatch reduction strategies is essential to mitigate bycatch impacts while ensuring fisher livelihoods.

Artificial light has been used by fishers for thousands of years to attract fish and increase catch efficiency (Nguyen and Winger, 2019; Yochum et al., 2024). More recently, net illumination has emerged as a

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promising bycatch reduction technology that can reduce bycatch of marine megafauna in coastal gillnet fisheries across multiple ocean basins (Lucas and Berggren, 2022; Huang et al., 2024). To date, the majority of net illumination studies have focused on sea turtles and other marine megafauna, most of which have found reductions in bycatch while maintaining target fish catch in gillnet fisheries operating at night (Allman et al., 2020; Bielli et al., 2020; Burgher et al., 2026; Darquea et al., 2020; Gautama et al., 2022; Kakai, 2019; Mangel et al., 2018; Ortiz et al., 2016; Senko et al., 2022, 2025; Snape et al., 2024; Virgili et al., 2018; Wang et al., 2010, 2013). Some studies, however, have found no reductions or increased bycatch, particularly for sea birds (Field et al., 2019; Jančič et al., 2025; Martínez-Baños and Maynou, 2018; Post et al., 2024; Sigurdsson, 2023). Moreover, Senko et al. (2022) found that net illumination can improve the efficiency of fishery operations by reducing the time it takes fishers to haul and disentangle their nets.

Despite these promising results, research shows that responses to artificial illumination are highly variable depending on species, as well as the color and type of light used (Wang et al., 2010; Yu et al., 2022, 2023; Nguyen and Winger, 2019). Although all published net illumination studies have assessed the effects of illumination on aggregate target fish catch, it is not yet known how fish respond across multiple taxonomic groups and within different taxonomic levels. Furthermore, most studies have used green LED lights (Allman et al., 2020; Bielli et al., 2020; Burgher et al., 2026; Gautama et al., 2022; Kakai, 2019; Mangel et al., 2018; Ortiz et al., 2016; Senko et al., 2022, 2025; Snape et al., 2024; Wang et al., 2010), limiting our understanding of how net illumination performs across different wavelengths and illumination methods. Here, we conducted controlled fishery experiments in Mexico's Gulf of California using four different light types that emitted different wavelengths (ranging from 395 to 600 nm) to examine the effects of artificial gillnet illumination on a diverse array of cartilaginous and bony fish species.

2. Methods

2.1. Data collection

Paired net illumination trials were conducted in a mixed-species commercial bottom-set gillnet fishery in the Gulf of California near Bahía de los Ángeles, Baja California, Mexico, from 2008 to 2014 during June and July (see Wang et al. (2010) for a map). This fishery represents a typical bottom-set gillnet fishery in Baja California, Mexico (Wang et al., 2010). Fishers use monofilament gillnets to target a variety of fish species, though catch during our study was primarily composed of spotted sand bass (*Paralabrax maculatofasciatus*) and California halibut (*Paralichthys californicus*). Although bycatch rates are poorly documented in this specific fishery, there is known bycatch of sea turtles (Nichols, 2003; Wang et al., 2010), which has been identified as a conservation concern in similar gillnet fisheries across the Baja peninsula (Peckham et al., 2007; Mancini et al., 2012; Koch et al., 2006; Senko et al., 2014a; Senko et al., 2017). While a few species of elasmobranchs may occasionally be retained (most notably in our study, the Dusky Smooth-hound Shark, *Mustelus canis*), the vast majority are discarded as bycatch.

For each trial, a similar-sized control net and an illuminated net were set in locations with similar ocean-floor topography 200 m apart at sunset and soaked overnight. The monofilament nets were 1.5 m tall and ranged from 60 to 400 m long. A total of 106 paired trials were completed with four types of artificial illumination: green light-emitting diodes (LEDs) ($n = 23$), chemiluminescent green glowsticks ($n = 18$), orange LEDs ($n = 29$), and ultraviolet (UV) LEDs ($n = 36$). All LEDs were commercially available Electralume lights (Lindgren-Pitman) with identical designs differing only in emitted wavelength: 395 nm (UV), 520 nm (green), and 600 nm (orange). The green glowsticks (Blackrock) were 15.25 cm in length and had an approximate peak spectral wavelength of 510 nm.

LED lights were placed 10 m apart on the float line, while glowsticks were placed every 5 m to account for their lower light intensity. Lights were placed on both control and illuminated nets, with control lights deactivated to control for any effects of the illuminated device (e.g., weight). This control configuration allowed us to specifically assess the effects of illumination on catch rates. At the end of each soak, fish were counted and classified by species. If a fish could not be identified by species, it was classified at the most specific taxonomic level possible (e.g., 56 sharks were classified under the order Carcharhiniformes). Supplementary Table S1 lists counts for each species captured. The Mexican government through the Comisión Nacional de Áreas Naturales Protegidas (CONANP) authorized this research. All animal handling procedures were in compliance with the IACUC protocols of the University of Hawaii, Manoa.

2.2. Broad-scale generalized linear mixed-effects models

To assess how bony fish and elasmobranchs respond to four types of artificial illumination, we fitted two Generalized Linear Mixed-Effects Models (GLMMs), one for each taxon, using ‘glmer.nb’ from the ‘lme4’ package in R 4.2.1 (Bates et al., 2015; R Core Team, 2022). Our dependent variable (Y_i), representing the number of fish caught per set, is modeled with a negative binomial distribution due to overdispersion.

Global models (i.e., models containing all possible variables) for 1) bony fish and 2) elasmobranchs included net treatment (i.e., control vs. illuminated) and light type (i.e., green LEDs, green glowsticks, UV LEDs, and orange LEDs) as fixed variables, connected by an interaction term, and the natural logarithm of unit effort (log[(net length [m]/100)*(soak time [hr]/12)]) as an offset term to account for differences in fishing effort between sets. To account for variation between trials, global models also included date, location, depth, and experiment ID as random effects. Fisher and net orientation (e.g. North-South, East-West) were included as fixed effects to prevent inaccurate variance estimation resulting from too few categories for each variable (Harrison et al., 2018).

We used Akaike's information criterion (AIC) to select the best-fit models (Burnham and Anderson, 2010). *P*-values for net treatment and interactions were obtained using the ‘Anova’ function in the ‘car’ package (Fox and Weisberg, 2019). The ‘predict’ function from the ‘stats’ package was used to obtain the expected elasmobranch and bony fish catch, which was then standardized by unit effort ([net length/100 m] × [net soak time/12 h]) (R Core Team, 2022).

2.3. Fine-scale order analyses

To elucidate the fine-scale taxonomic effects of net illumination on a variety of bony fish and elasmobranch groups, we examined the effects of net illumination on each order captured. We performed the analysis at the order level due to sample size limitations that arose when reducing fish into family or species classifications. We calculated catch per unit effort (CPUE = number of fish/([net length/100 m] × [net soak time/12 h])) for each order to account for varying net lengths and soak times. Then, we performed paired *t*-tests to determine whether each order's CPUE was significantly different in illuminated versus control nets. To identify differences in performance among different lights, we ran tests for each of the four light types. However, for some orders, small sample sizes precluded meaningful analyses of individual light types; thus, we also performed tests for each order when all light types were combined to understand how taxa were generally affected by net illumination.

For all tests, normality was assessed using Shapiro-Wilks tests and Q-Q plots. When the data violated the assumption of normality, we attempted log transformation. To account for zero values for catch, we added one to CPUE values before transforming. When log transformation did not rescue the assumption of normality, we used Wilcoxon signed-rank tests. Effect sizes are calculated as Cohen's d (i.e., difference in group means/pooled standard deviation). All hypotheses were tested at a significance level of 0.05. Data were analyzed and visualized in R 4.2.1 (R Core Team, 2022).

3. Results

3.1. Overview of fishing effort and catch

We fished over 65,000 m of net (control = 32,510 m of net, mean ± SD = 306.7 ± 69.0; illuminated = 32,715 m of net, mean ± SD = 308.6 ± 66.3) with 2569 total hours of soak time (control = 1291.6 h, mean ± SD = 12.2 ± 0.74, illuminated = 1277.8 h, mean ± SD = 12.1 ± 0.70). We captured a total of 13,164 individual fish, belonging to 43 species and 20 orders. We captured 8698 bony fish (27 species, 13 orders) and 4466 elasmobranchs (16 species, 7 orders). Supplementary Table S1 lists counts for each species captured.

3.2. Effects of net illumination on elasmobranchs

The best-fit GLMM selected to predict elasmobranch catch is:

$$\sim \ Net\ Treatment{*}Light\ Type + offset(\log(effort)) + Net\ Orientation + (1 \mid Location) + (1 \mid Date)$$

A summary of model results is presented in Table 1, while detailed model results, including fixed effect estimates and variance for random effects, are presented in Supplementary Table S2. Aggregate elasmobranch catch is significantly reduced in illuminated nets when using each of the four light types ($p \le 0.001$; Fig. 1a). However, there is a significant interaction between treatment and light type ($p = 0.021$), indicating that the light types have varied effects on elasmobranch catch. Orange LEDs were the most effective for reducing elasmobranch catch (−54.5% CPUE), followed by green glowsticks (−32.1% CPUE), green LEDs (−30.2% CPUE), and UV LEDs (−23.1% CPUE; Fig. 1b).

Of the five elasmobranch orders caught with sufficient sample size for analysis, we found four elasmobranch orders with significantly lower CPUE in illuminated nets when all light types were combined for analysis: Carcharhiniformes (ground sharks; effect size = −0.63; $p < 0.001$), Myliobatiformes (stingrays, manta rays, and eagle rays; effect size = −0.54; $p = 0.018$), Rhinopristiformes (guitarfish/shovelnose rays; effect size = −0.56; p < 0.001), and Torpediniformes (electric rays; effect size = −0.31; $p = 0.032$; Fig. 2; Table 2). Insufficient sample sizes prevented analyses for Heterodontiformes ($n = 2$) and Lamniformes ($n = 1$). When breaking down each order's catch by light type, we see that Carcharhiniformes (effect size = −0.91; p < 0.001) and Myliobatiformes (effect size = −1.17; p = 0.032) have significantly lower catch in orange illuminated nets, while Rhinopristiformes have significantly lower catch in orange (effect size = −1.13; p < 0.001), UV (effect size = −0.58; $p = 0.005$), and glowstick (effect size = −0.64; $p = 0.049$) illuminated nets (Table 3). Small sample sizes and low power limited robust analysis for all other elasmobranch order and light type combinations. Species belonging to orders with significantly lower catch in illuminated nets are listed in Supplementary Table S3, with their IUCN Redlist Status.

Table 1

Best-fit model regression coefficients (Est.), standard errors (SE), and *p*-values detailing predicted effects of illumination treatment, light type, and their interaction on elasmobranchs and bony fish CPUE. The intercept baseline group is “glowstick” for light type and “control” for treatment. Full model results can be found in Supplementary Table S2.

	Elasmobranchs			Bony Fish		
Predictor	Est.	SE	p-value	Est.	SE	p-value
Intercept	1.545	0.240	<0.001	2.503	0.314	<0.001
Treatment - Illuminated	−0.381	0.146	0.009	0.254	0.188	0.178
Light Type - Green	0.199	0.236	0.400	−0.722	0.339	0.033
Light Type - Orange	0.986	0.217	<0.001	0.155	0.331	0.640
Light Type - UV	0.662	0.213	0.002	−0.103	0.315	0.744
Interaction - Green x Illuminated	0.021	0.206	0.921	−0.255	0.262	0.330
Interaction - Orange x Illuminated	−0.362	0.191	0.059	−0.335	0.268	0.212
Interaction - UV x Illuminated	0.133	0.185	0.470	−0.467	0.245	0.056

3.3. Effects of net illumination on bony fish

The best-fit GLMM selected for bony fish is:

$$\sim \ Net\ Treatment{*}Light\ Type + offset(\log(effort)) + Fisher + (1 \mid Experiment\ ID) + (1 \mid Date)$$

A summary of model results is presented in Table 1, while detailed model results, including fixed effect estimates and variance for random effects, are presented in Supplementary Table S2. Aggregate bony fish catch is not significantly affected by net illumination of any kind ($p = 0.756$; Fig. 1c). Additionally, there is no significant interaction between treatment and light type ($p = 0.231$), indicating that the effects of each light type on bony fish catch are statistically similar (Fig. 1d).

Siluriformes (catfish) was the only bony fish order with significantly lower CPUE in illuminated nets when all light types were combined for analysis (effect size = −0.55; $p = 0.001$; Fig. 2; Table 2). When breaking down catch by light type, we find that Siluriformes has significantly lower CPUE in UV-illuminated nets (effect size = −0.49; $p = 0.031$). While orange LED-illuminated nets showed no significant change in Siluriformes CPUE, the effect size was relatively large (−0.63) and the *p*-value was close to the significance level ($p = 0.06$). Similarly, there was no significant change in Siluriformes CPUE in glowstick-illuminated nets ($p = 0.25$), though effect size was large (−3.77) and catch rates were extremely low ($n = 3$). No Siluriformes was caught during trials using green LEDs (Table 3).

While there was no significant change in Perciformes catch when all light types were combined (Table 2), Perciformes showed varied responses to individual light types (Table 3). UV LEDs significantly decreased CPUE (effect size = −0.71; $p = 0.006$), while orange LEDs showed a non-significant decrease in CPUE (effect size = −0.62; $p = 0.102$). Conversely, green LEDs (effect size = 0.56; $p = 0.518$) and glowsticks (effect size = 0.65; $p = 0.233$) both led to non-significant increases in CPUE. Species belonging to orders with significantly different catch in illuminated nets, including Siluriformes and Perciformes, are listed in Supplementary Table S3, with their IUCN Redlist Status.

4. Discussion

Although net illumination has been found to reduce sea turtle and other marine megafauna bycatch in most studies (Allman et al., 2020; Bielli et al., 2020; Darquea et al., 2020; Gautama et al., 2022; Kakai, 2019; Mangel et al., 2018; Ortiz et al., 2016; Senko et al., 2022, 2025; Snape et al., 2024; Virgili et al., 2018; Wang et al., 2010, 2013), major knowledge gaps include understanding 1) how a diverse array of fish respond across multiple taxonomic groups and within different taxonomic levels; and 2) how these responses may vary across different light types and wavelengths. Here, we present the first assessment of taxa-specific effects of gillnet illumination using multiple light types on elasmobranchs and bony fish. We found that elasmobranch (i.e., shark and ray) catch was significantly decreased in gillnets artificially illuminated with four types of light (i.e., orange LED, ultraviolet LED, green LED, and green glowstick), with orange LEDs being the most effective (Fig. 1a & 1b). Net illumination had no significant effect on aggregate bony fish catch (Fig. 1c & 1d), although order-level analyses revealed varied responses to net illumination at finer taxonomic scales (Tables 2

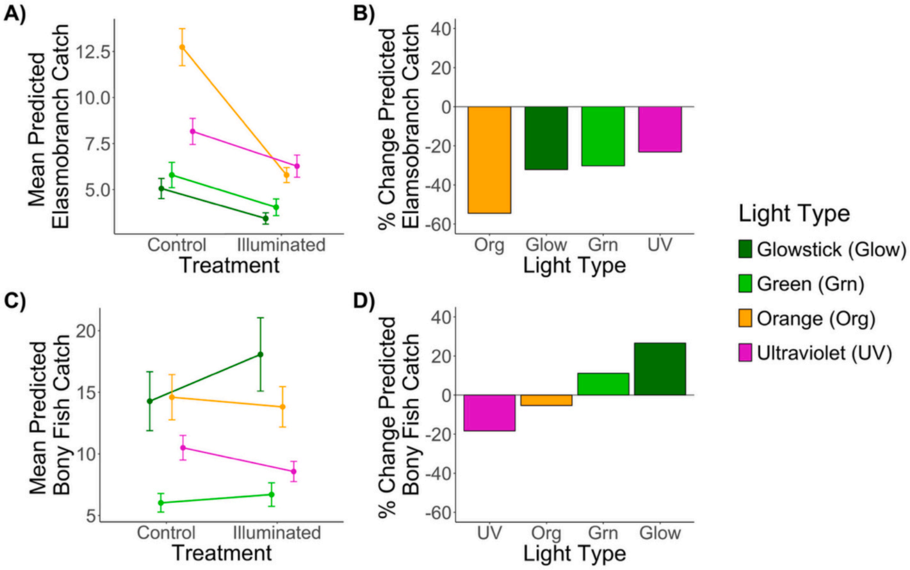

Fig. 1. Mean predicted catch (A) and percentage change in mean predicted catch (B) for elasmobranchs in illuminated nets and mean predicted catch (C) and percentage change in mean predicted catch (D) for bony fish in illuminated nets. Mean predicted catch in elasmobranchs (A) and bony fish (C) are standardized by unit effort ([net length (m)/100 m]*[soak time (hr)/12 h]) for each net treatment and light type, with error bars representing standard error.

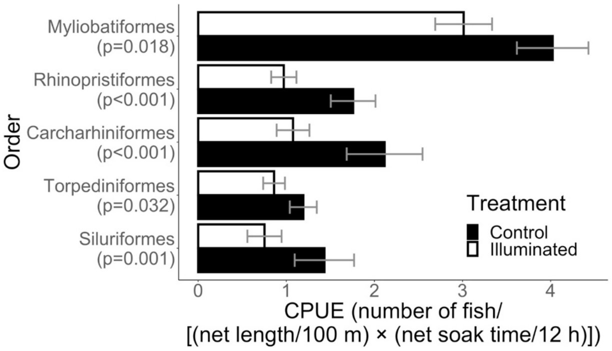

Fig. 2. Mean catch per unit effort (CPUE) in control and illuminated nets for orders significantly affected by net illumination when all light types are combined for analysis. Error bars represent standard error. Siluriformes is the only bony fish order with significantly different CPUE in illuminated nets.

& 3). These results suggest that net illumination can effectively reduce elasmobranch bycatch and maintain most bony fish catch, while also providing taxonomic specificity that is critical for informing evidence-based fisheries management at local and global scales.

Several elasmobranch species are threatened by overfishing and bycatch, necessitating mitigation solutions (Dulvy et al., 2014; Pacoureau et al., 2021; Worm et al., 2013; Dulvy et al., 2024; Worm et al., 2024). Net illumination shows promise for reducing elasmobranch bycatch in gillnets across multiple light types and orders. Here, all four light types reduced elasmobranch catch, with reductions ranging from 23% to 55% (Fig. 1a & 1b). These results confirm previous recent research (i.e., Senko et al., 2022; Snape et al., 2024) that found significant decreases in elasmobranch bycatch using green LEDs, suggesting that net illumination can reduce elasmobranch bycatch across multiple fisheries, even in geographically distant and diverse ecosystems. However, this study also analyzes elasmobranch catch at a finer taxonomic scale (order), finding bycatch reductions in four elasmobranch orders (Carcharhiniformes, Myliobatiformes, Rhinopristiformes, and Torpediniformes; Fig. 2). Of the 14 species captured belonging to these orders, 7 are globally listed as Vulnerable or greater by the IUCN Red List (Supplementary Table S3). Therefore, net illumination appears to be effective for many elasmobranchs of conservation concern and should be explored as a bycatch reduction solution in fisheries with high elasmobranch bycatch.

Without accounting for taxonomy, we found no significant effects of net illumination on aggregate bony fish catch, suggesting that bony fish catch can be maintained with illuminated nets. Similarly, other studies found no effect of net illumination on bony fish catch using either UV or green LEDs (Allman et al., 2020; Bielli et al., 2020; Darquea et al., 2020; Senko et al., 2022, 2025; Snape et al., 2024; Wang et al., 2010, 2013), indicating that multiple wavelengths and light types can maintain fishing production across fisheries where bony fish are the primary target catch. While we found no change in aggregate bony fish catch, UV LEDs significantly decreased Siluriformes (i.e., catfish) and Perciformes catch. Additionally, orange LEDs nearly significantly reduced Siluriformes catch ($p = 0.06$, effect size $= -0.63$). Some bony fish species may respond differently to artificial net illumination due to potential differences in 1) physiology, 2) behavioral responses to the light itself, and 3) behavioral responses to environmental changes created by the light (e.g., attracting prey; Utne-Palm et al., 2018; Humborstad et al., 2018; Yu et al., 2022, 2023; Yochum et al., 2024). Thus, more research is needed to understand species-specific responses to net illumination, particularly for vulnerable and economically valuable species (Kashyap et al., 2023; Yochum et al., 2024).

It is unclear why fish have varied responses to net illumination. In our study, nearly all fish with significantly different catch in illuminated gillnets (i.e., Siluriformes and elasmobranchs) possess electroreception, allowing them to sense electrical fields to locate prey and detect predators or conspecifics (Newton et al., 2019; Whitehead and Collin, 2004). Lights on illuminated nets emit novel electrical fields different from those produced by fish that are regularly encountered in the wild, which may overstimulate these fish, causing them to avoid illuminated nets (Jordan et al., 2013). Bycatch deterrent devices emitting active electrical fields have elicited aversive responses in elasmobranchs during lab experiments (Howard et al., 2018), and significantly reduced blue shark (−91.3%) and ray bycatch (71.3%) in a pelagic longline fishery (Doherty et al., 2022). However, to effectively harness these technologies for bycatch reduction in nets, more research is needed to understand variations in elasmobranch responses to artificial electrical fields, and whether electrical fields emitted by lights on illuminated nets influence elasmobranch catch in addition to the light stimulus.

The four types of light used for this study had varied effects,

Table 2
Mean CPUE in control and illuminated nets for each elasmobranch and bony fish order, along with effect size (Cohen's d), the number of paired trials included in the statistical tests, and the total number of fish caught from each order.

Order	Mean Control CPUE	Mean Illuminated CPUE	p-value	Effect Size	# Paired Trials	# Fish
ELASMOBRANCHS						
Myliobatiformes*	**4.02**	**3.01**	**0.018**	**−0.54**	**95**	**2196**
Rhinopristiformes*	**1.76**	**0.97**	**<0.001**	**−0.56**	**100**	**807**
Carcharhiniformes*	**2.12**	**1.08**	**<0.001**	**−0.63**	**78**	**797**
Torpediniformes*	**1.19**	**0.86**	**0.032**	**−0.31**	**72**	**432**
Rajiformes	1.28	0.85	0.171	−0.38	43	230
Heterodontiformes	0.00	0.26	NA	NA	2	2
Lamniformes	0.00	0.94	NA	NA	1	2
BONY FISH						
Scombriformes	5.68	5.13	0.973	−0.19	93	3547
Perciformes	3.28	3.09	0.129	−0.10	105	2189
Pleuronectiformes	1.03	1.15	0.316	0.12	103	680
Acanthuriformes	1.02	1.97	0.401	0.55	61	629
Aulopiformes	1.46	1.08	0.888	−0.25	72	602
Clupeiformes	1.91	1.22	0.394	−0.36	56	589
Siluriformes*	**1.43**	**0.75**	**0.001**	**−0.55**	**34**	**236**
Tetraodontiformes	0.42	0.37	0.760	−0.06	52	137
Characiformes	1.90	3.41	0.424	0.73	3	49
Carangiformes	0.39	0.20	0.361	−0.28	16	31
Mugiliformes	0.17	0.13	0.578	−0.12	7	7
Beloniformes	0.00	0.28	NA	NA	1	1
Labriformes	0.00	0.53	NA	NA	1	1

Notes: Orders with significantly different catch in illuminated nets are noted in bold and with an asterisk (*).

Table 3
Effects of four individual types of net illumination on each order caught during trials, including p-value, effect size (Cohen's d), the number of paired trials, and the number of fish caught for each order and light type.

	Orange				UV				Green				Glowstick			
Order	p-value	Effect Size	# Trials	# Fish	p-value	Effect Size	# Trials	# Fish	p-value	Effect Size	# Trials	# Fish	p-value	Effect Size	# Trials	# Fish
ELASMOBRANCHS																
Myliobatiformes	**0.032**	**−1.17**	**29**	**732**	0.283	−0.27	35	1174	0.772	−0.11	13	41	0.223	−0.56	18	249
Rhinopristiformes	**<0.001**	**−1.13**	**25**	**212**	**0.005**	**−0.58**	**36**	**337**	0.505	−0.21	21	165	**0.049**	**−0.64**	**18**	**93**
Carcharhiniformes	**<0.001**	**−0.91**	**27**	**475**	*0.054*	*−0.40*	*28*	*186*	0.167	−0.82	9	53	0.119	−0.70	14	103
Torpediniformes	0.201	−0.32	21	123	0.293	−0.23	26	184	*0.079*	*−0.78*	*14*	*96*	0.169	0.41	11	29
Rajiformes	0.561	−0.24	7	11	NA	NA	0	0	0.199	−0.65	19	113	0.936	−0.12	17	106
Heterodontiformes	NA	NA	0	0	NA	NA	0	0	NA	NA	0	0	NA	NA	2	3
Lamniformes	NA	NA	0	0	NA	NA	0	0	NA	NA	1	2	NA	NA	0	0
BONY FISH																
Scombriformes	0.643	−0.60	26	1165	0.247	−0.66	34	994	0.589	−0.13	16	137	0.297	0.86	17	1251
Perciformes	0.102	−0.62	29	513	**0.006**	**−0.71**	**35**	**685**	0.518	0.56	23	253	0.233	0.65	18	738
Pleuronectiformes	0.939	−0.02	28	240	0.109	0.32	34	253	0.948	0.08	23	104	0.805	0.07	18	83
Acanthuriformes	0.254	0.77	17	169	0.318	0.72	30	412	0.875	0.41	4	6	0.151	−0.52	10	42
Aulopiformes	0.140	0.44	23	178	0.128	−0.55	27	287	0.647	−0.73	11	53	0.430	−0.31	11	84
Clupeiformes	0.542	−0.06	21	333	*0.098*	*−0.48*	*19*	*110*	0.546	−1.11	6	43	0.625	−0.91	10	103
Siluriformes	*0.061*	*−0.63*	*18*	*156*	**0.031**	**−0.49**	**13**	**77**	NA	NA	0	0	0.250	−3.77	3	3
Tetraodontiformes	0.135	−0.09	14	40	0.256	−0.27	14	29	0.876	0.06	10	13	0.845	0.05	14	55
Characiformes	NA	NA	2	48	NA	NA	1	1	NA	NA	0	0	NA	NA	0	0
Carangiformes	0.385	−0.43	7	21	0.716	−0.13	6	7	NA	NA	0	0	0.500	−0.25	3	3
Mugiliformes	0.875	−0.39	4	4	NA	NA	0	0	NA	NA	0	0	1.000	0.23	3	3
Beloniformes	NA	NA	0	0	NA	NA	0	0	NA	NA	0	0	NA	NA	1	1
Labriformes	NA	NA	0	0	NA	NA	0	0	NA	NA	1	1	NA	NA	0	0

Notes: Significant differences ($p < 0.05$) are indicated by bolded text, while nearly significant differences ($0.05 < p < 0.1$) are indicated by italicized text.

suggesting species responses to net illumination may depend on wavelength and light type. The variable catch rates across the four paired treatments highlight the inherent variability associated with conducting experiments in real-world fisheries. For example, the control nets for the orange LED paired trials had higher observed CPUE than any other net type. This variability most likely stems from extraneous factors, such as date, fishing location, and environmental conditions. We controlled for these variables as much as possible through our paired experimental design and statistical modelling, as recommended by Yochum et al. (2024). Specifically, the paired design ensured that each control and illuminated net pair were exposed to the same conditions, while the model specification accounted for these pairs and allowed us to calculate predicted reductions for each light type using only the control trials paired with that light type (as opposed to calculating reductions for each light type using all control trials). Therefore, it is unlikely that the comparatively large reduction using orange light is due to coincidentally high catch in control nets. Rather, this reduction represents a robust finding reflecting species variable responses to different types of net illumination.

In addition to controlling for environmental variability, we also accounted for potential gear-related effects of illumination devices. Specifically, our study utilized deactivated lights on control nets to specifically test for the effects of illumination, controlling for any effects of mounting the illumination devices on the nets (e.g., changes in net profile and catch efficiency). These physical effects of the illumination device likely differ depending on the exact device used. Given that there are many commercially available light options with varying characteristics (e.g., weight, size, materials), it is important to understand how the chosen device specifically influences catch, with and without active illumination (Yochum et al., 2024).

While it is unclear why some wavelengths performed better than others, the design of elasmobranch vision systems may play a role. Elasmobranchs have well-developed eyes and see a wide range of light intensities (Hart et al., 2006; Hart and Collin, 2015). Color vision in elasmobranchs, however, is limited or nonexistent, particularly in sharks (Hart et al., 2006; Lisney et al., 2012). Elasmobranchs most likely rely on high contrast sensitivity (i.e., the ability to distinguish between an object and its background) to discern features of their environment, such as fishing nets (Hart, 2020; Hart and Collin, 2015). Bright lights in colors optimized for high visual contrast between fishing gear and the environment (e.g., orange) may be the most effective net illumination strategy for elasmobranch bycatch reduction. Nevertheless, elasmobranch visual systems are highly diverse and their behavioral responses to light may be affected by environmental conditions (e.g., turbidity, ambient light), behavioral states, and life history (Burgher et al., 2026; Hart and Collin, 2015; O'Farrell et al., 2024), leading to varied responses to net illumination. Understanding how both environmental and behavioral factors affect net illumination performance will help fishery managers determine whether net illumination could be an effective bycatch solution for coastal gillnet fisheries (Yochum et al., 2024). Our findings highlight the need to account for taxonomic variation in sensory capabilities and behavior when evaluating net illumination, while also providing clear justification for further comparison of light types across diverse fisheries and environmental contexts.

CRediT authorship contribution statement

Kayla M. Burgher: Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Formal analysis, Data curation. **John Wang:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Joel Barkan:** Resources, Project administration, Investigation. **Yonat Swimmer:** Writing – review & editing, Resources, Investigation, Conceptualization. **Jesse F. Senko:** Writing – review & editing, Supervision, Resources, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.biocon.2026.111732.

Data availability

Data will be made available on request.

References

Allman, Phil, Andrews Agyekumhene, Leyna Stemle, 2020. Gillnet illumination as an effective measure to reduce sea turtle bycatch. Conserv. Biol. 0 (0), 1–9. https://doi.org/10.1111/cobi.13647.

Bates, Douglas, Mächler, Martin, Bolker, Ben, Walker, Steve, 2015. Fitting linear mixed-effects models using **Lme4**. J. Stat. Softw. 67 (1). https://doi.org/10.18637/jss.v067.i01.

Bielli, Alessandra, Alfaro-shigueto, J., Doherty, P.D., et al., 2020. An illuminating idea to reduce bycatch in the Peruvian small-scale gillnet fishery. Biol. Conserv. 241, 108277. https://doi.org/10.1016/j.biocon.2019.108277.

Burgher, Kayla M., Denton, Kyli E., Wang, John, Peckham, S. Hoyt, Aguilar-Ramirez, Daniel, Senko, Jesse F., 2026. Net illumination is more effective for reducing fisheries bycatch at night. Rev. Fish Biol. Fish. 36 (1), 27. https://doi.org/10.1007/s11160-025-10016-1.

Burnham, Kenneth P., Anderson, David Ray, 2010. Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach, 2. ed. Springer.

Cashion, Tim, Dalal Al-Abdulrazzak, Belhabib, Dyhia, et al., 2018. Reconstructing global marine fishing gear use: catches and landed values by gear type and sector. Fish. Res. 206 (October), 57–64. https://doi.org/10.1016/j.fishres.2018.04.010.

Darquea, Jodie J., Ortiz-alvarez, Clara, Córdova-zavaleta, Francisco, et al., 2020. Trialing net illumination as a bycatch mitigation measure for sea turtles in a small-scale gillnet fishery in Ecuador. Lat. Am. J. Aquat. Res. 48 (3), 446–455. https://doi.org/10.3856/vol48-issue3-fulltext-2428.

Davies, R.W.D., Cripps, S.J., Nickson, A., Porter, G., 2009. Defining and estimating global marine fisheries bycatch. Mar. Policy 33 (4), 661–672. https://doi.org/10.1016/j.marpol.2009.01.003.

Doherty, Philip D., Enever, Robert, Omeyer, Lucy C.M., et al., 2022. Efficacy of a novel shark bycatch mitigation device in a tuna longline fishery. Curr. Biol. 32 (22), R1260–R1261. https://doi.org/10.1016/j.cub.2022.09.003.

Dulvy, Nicholas K., Fowler, Sarah L., Musick, John A., et al., 2014. Extinction risk and conservation of the world's sharks and rays. eLife 3 (January), e00590. https://doi.org/10.7554/eLife.00590.

Dulvy, Nicholas K., Pacoureau, Nathan, Matsushiba, Jay H., et al., 2024. Ecological erosion and expanding extinction risk of sharks and rays. Science 386 (6726), eadn1477. https://doi.org/10.1126/science.adn1477.

FAO, 2022. The State of World Fisheries and Aquaculture 2022. In: Towards Blue Transformation. The State of the World. FAO.

Field, Rob, Crawford, Rory, Enever, Robert, et al., 2019. High contrast panels and lights do not reduce bird bycatch in Baltic sea gillnet fisheries. Glob. Ecol. Conserv. 18 (April), e00602. https://doi.org/10.1016/j.gecco.2019.e00602.

Fox, John, Weisberg, Sanford, 2019. An {R} Companion to Applied Regression, V. Third. Sage. released. https://socialsciences.mcmaster.ca/jfox/Books/Companion/.

Gautama, Dwi Ariyoga, Susanto, Hendro, Riyanto, Mochammad, Wahju, Ronny I., Osmond, Michael, Wang, John H., 2022. Reducing sea turtle bycatch with net illumination in an Indonesian small-scale coastal gillnet fishery. Front. Mar. Sci. 9 (November), 1036158. https://doi.org/10.3389/fmars.2022.1036158.

Gibbs, Sarah L., Murphy, Robert D., Harris, Bradley P., Grabowski, Jonathan H., Scyphers, Steven B., 2025. Threats perceived by five prominent U.S. commercial fisheries. N. Am. J. Fish Manag., vqaf075 https://doi.org/10.1093/najfmt/vqaf075.

Gilman, Eric, Clarke, Shelley, Brothers, Nigel, et al., 2008. Shark interactions in pelagic longline fisheries. Mar. Policy 32 (1), 1–18. https://doi.org/10.1016/j.marpol.2007.05.001.

Harrison, Xavier A., Donaldson, Lynda, Correa-Cano, Maria Eugenia, et al., 2018. A brief introduction to mixed effects modelling and multi-model inference in ecology. PeerJ 6 (May), e4794. https://doi.org/10.7717/peerj.4794.

Hart, Nathan S., 2020. Vision in sharks and rays: opsin diversity and colour vision. Semin. Cell Dev. Biol. 106 (October), 12–19. https://doi.org/10.1016/j.semcdb.2020.03.012.

Hart, Nathan S., Collin, Shaun P., 2015. Sharks senses and shark repellents. Integrative Zoology 10 (1), 38–64. https://doi.org/10.1111/1749-4877.12095.

Hart, Nathan S., Lisney, Thomas J., Collin, Shaun P., 2006. Visual communication in elasmobranchs. In: Communication in Fishes. Science Publishers Inc.

He, Pingguo, Chopin, Frank, Suuronen, Petri, Ferro, Richard S.T., Lansley, Jon, 2021. Classification and illustrated Definition of Fishing Gears. No. 672. FAO Fisheries and Aquaculture Technical Paper. FAO. https://doi.org/10.4060/cb4966en.

Howard, Sunkita, Brill, Richard, Hepburn, Chris, Rock, Jenny, 2018. Microprocessor-based prototype bycatch reduction device reduces bait consumption by spiny dogfish and sandbar shark. ICES J. Mar. Sci. 75 (6), 2235–2244. https://doi.org/10.1093/icesjms/fsy098.

Huang, Cheng, Rice, Jake, Richter, Andries, et al., 2024. Effects of fishery bycatch-mitigation measures on vulnerable marine fauna and target catch. Nat. Sustainability. https://doi.org/10.1038/s41893-024-01422-7 ahead of print, September 4.

Humborstad, Odd-Børre, Utne-Palm, Anne Christine, Breen, Michael, Løkkeborg, Svein, 2018. Artificial light in baited pots substantially increases the catch of cod (Gadus Morhua) by attracting active bait, krill (Thysanoessa Inermis). ICES J. Mar. Sci. 75 (6), 2257–2264. https://doi.org/10.1093/icesjms/fsy099.

Jančič, Matic, Benussi, Matteo, Amančić, Sven, Mackelworth, Peter, Holcer, Draško, Lazar, Bojan, 2025. Is net illumination a silver bullet for mitigating Sea turtle bycatch in set net fisheries? Biol. Conserv. 302 (February), 110851. https://doi.org/10.1016/j.biocon.2024.110851.

Jordan, L.K., Mandelman, J.W., McComb, D.M., Fordham, S.V., Carlson, J.K., Werner, T. B., 2013. Linking sensory biology and fisheries bycatch reduction in elasmobranch fishes: a review with new directions for research. Conserv. Physiol. 1 (1), cot002–cot002. https://doi.org/10.1093/conphys/cot002.

Kakai, Timothy M., 2019. Assessing the effectiveness of LED lights for the reduction of sea turtle bycatch in an artisanal gillnet fishery - a case study from the north coast of Kenya. Western Indian Ocean Journal of Marine Science 18 (2), 37–44. https://doi.org/10.4314/wiojms.v18i2.4.

Kashyap, Suman, Chandravanshi, Morajdhwaj, Meena, Praveen Kumar, et al., 2023. A systematic review on challenges and conservation strategies for marine megafauna. Int. J. Environ. Clim. Change 13 (9), 2578–2590. https://doi.org/10.9734/ijecc/2023/v13i92491.

Koch, Volker, Nichols, Wallace J., Peckham, Hoyt, de la Toba, Victor, 2006. Estimates of sea turtle mortality from poaching and bycatch in Bahía Magdalena, Baja California Sur, Mexico. Biol. Conserv. 128 (3), 327–334. https://doi.org/10.1016/j.biocon.2005.09.038.

Lewison, R., Crowder, L., Read, A., Freeman, S., 2004. Understanding impacts of fisheries bycatch on marine megafauna. Trends Ecol. Evol. 19 (11), 598–604. https://doi.org/10.1016/j.tree.2004.09.004.

Lisney, T.J., Theiss, S.M., Collin, S.P., Hart, N.S., 2012. Vision in elasmobranchs and their relatives: 21st century advances. J. Fish Biol. 80 (5), 2024–2054. https://doi.org/10.1111/j.1095-8649.2012.03253.x.

Lively, Julie A., McKenzie, Jonathan, 2023. Discards and bycatch: A review of wasted fishing. In: Advances in Marine Biology, 95. Elsevier. https://doi.org/10.1016/bs.amb.2023.07.001.

Lucas, Sol, Berggren, Per, 2022. A systematic review of sensory deterrents for bycatch mitigation of marine megafauna. Rev. Fish Biol. Fish. 33 (November), 1–33. https://doi.org/10.1007/s11160-022-09736-5.

Majluf, Patricia, Babcock, Elizabeth A., Riveros, Juan Carlos, Schreiber, Milena Arias, Alderete, William, 2002. Catch and bycatch of sea birds and marine mammals in the small-scale fishery of Punta San Juan, Peru. Conserv. Biol. 16 (5), 1333–1343. https://doi.org/10.1046/j.1523-1739.2002.00564.x.

Mancini, Agnese, Koch, Volker, Seminoff, Jeffrey A., Madon, Bénédicte, 2012. Small-scale Gill-net fisheries cause massive green turtle *Chelonia Mydas* mortality in Baja California Sur, Mexico. Oryx 46 (1), 69–77. https://doi.org/10.1017/S0030605310001833.

Mangel, Jeffrey C., Wang, John, Alfaro-Shigueto, Joanna, et al., 2018. Illuminating gillnets to save seabirds and the potential for multi-taxa bycatch mitigation. R. Soc. Open Sci. 5, 180254.

Martínez-Baños, Pedro, Maynou, Francesc, 2018. Reducing discards in trammel net fisheries with simple modifications based on a guarding net and artificial light: contributing to marine biodiversity conservation. Sci. Mar. 82 (S1), 9–18. https://doi.org/10.3989/scimar.04710.03a.

Newton, Kyle C., Gill, Andrew B., Kajiura, Stephen M., 2019. Electroreception in marine fishes: Chondrichthyans. J. Fish Biol. 95 (1), 135–154. https://doi.org/10.1111/jfb.14068.

Nguyen, Khanh Q., Winger, Paul D., 2019. Artificial light in commercial industrialized fishing applications: A review. Reviews in Fisheries Science & Aquaculture 27 (1), 106–126. https://doi.org/10.1080/23308249.2018.1496065.

Nichols, Wallace J., 2003. "Biology and Conservation of Sea Turtles in Baja California, Mexico." Ph.D. Dissertation, The University of Arizona.

Northridge, Simon, Coram, Alex, Kingston, Al, Crawford, Rory, 2017. Disentangling the causes of protected-species bycatch in gillnet fisheries: causes of bycatch. Conserv. Biol. 31 (3), 686–695. https://doi.org/10.1111/cobi.12741.

O'Farrell, Halie B., Babcock, Elizabeth A., McCarthy, Kevin J., 2024. Bycatch mitigation for commonly caught shark species in the Gulf of Mexico reef bottom longline fishery. Marine and Coastal Fisheries 16 (5), e10310. https://doi.org/10.1002/mcf2.10310.

Oliver, Shelby, Braccini, Matias, Newman, Stephen J., Harvey, Euan S., 2015. Global patterns in the bycatch of sharks and rays. Mar. Policy 54 (April), 86–97. https://doi.org/10.1016/j.marpol.2014.12.017.

Ortiz, Natalia, Mangel, Jeffrey C., Wang, John, et al., 2016. Reducing green turtle bycatch in small-scale fisheries using illuminated gillnets: the cost of saving a sea turtle. Mar. Ecol. Prog. Ser. 545, 251–259. https://doi.org/10.3354/meps11610.

Pacoureau, Nathan, Rigby, Cassandra L., Kyne, Peter M., et al., 2021. Half a century of global decline in oceanic sharks and rays. Nature 589 (7843), 567–571. https://doi.org/10.1038/s41586-020-03173-9.

Panagopoulou, Aliki, Meletis, Zoë A., Margaritoulis, Dimitris, Spotila, James R., 2017. Caught in the same net? Small-scale fishermen's perceptions of fisheries interactions with sea turtles and other protected species. Front. Mar. Sci. 4 (JUN), 1–15. https://doi.org/10.3389/fmars.2017.00180.

Peckham, S. Hoyt, Diaz, David Maldonado, Walli, Andreas, Ruiz, Georgita, Crowder, Larry B., Nichols, Wallace J., 2007. Small-scale fisheries bycatch jeopardizes endangered Pacific loggerhead turtles. PLoS One 2 (10), e1041. https://doi.org/10.1371/journal.pone.0001041.

Post, Søren, Merkel, Flemming, Olesen, Malthe, Nørgaard, Nicoline, Hedeholm, Rasmus, 2024. Test of light emitting diodes (LED) as a possible bycatch mitigation measure in a gillnet fishery. Global Ecology and Conservation 52 (August), e02976. https://doi.org/10.1016/j.gecco.2024.e02976.

R Core Team, 2022. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing released. https://www.R-project.org/.

Read, Andrew J., Drinker, Phebe, Northridge, Simon, 2006. Bycatch of marine mammals in U.S. and global fisheries. Conserv. Biol. 20 (1), 163–169. https://doi.org/10.1111/j.1523-1739.2006.00338.x.

Senko, J., White, E.R., Heppell, S.S., Gerber, L.R., 2014b. Comparing bycatch mitigation strategies for vulnerable marine megafauna. Anim. Conserv. 17 (1), 5–18. https://doi.org/10.1111/acv.12051.

Senko, Jesse F., Hoyt Peckham, S., Aguilar-Ramirez, Daniel, Wang, John H., 2022. Net illumination reduces fisheries bycatch, maintains catch value, and increases operational efficiency. Curr. Biol. 32 (4), 911–918.e2. https://doi.org/10.1016/j.cub.2021.12.050.

Senko, Jesse F., Wang, John, Burgher, Kayla M., et al., 2025. Harnessing solar energy to reduce sea turtle bycatch. Conserv. Lett. 18 (5). https://doi.org/10.1111/conl.13151.

Senko, Jesse, Mancini, Agnese, Seminoff, Jeffrey A., Koch, Volker, 2014a. Bycatch and directed harvest drive high green turtle mortality at Baja California Sur, Mexico. Biol. Conserv. 169 (January), 24–30. https://doi.org/10.1016/j.biocon.2013.10.017.

Senko, Jesse, Jenkins, Lekelia D., Hoyt Peckham, S., 2017. At loggerheads over international bycatch: initial effects of a unilaterally imposed bycatch reduction policy. Mar. Policy 76 (February), 200–209. https://doi.org/10.1016/j.marpol.2016.11.017.

Shester, Geoffrey G., Micheli, Fiorenza, 2011. Conservation challenges for small-scale fisheries: bycatch and habitat impacts of traps and gillnets. Biol. Conserv. 144 (5), 1673–1681. https://doi.org/10.1016/j.biocon.2011.02.023.

Sigurdsson, Gm, 2023. Increase in bycatch rates of plunge- and surface-feeding seabirds observed while setting and hauling bottom set gillnets equipped with LED lights. Mar. Ecol. Prog. Ser. 720 (October), 191–194. https://doi.org/10.3354/meps14408.

Snape, Robin T.E., Beton, Damla, Broderick, Annette C., Omeyer, Lucy C.M., Godley, Brendan J., 2024. Flashing NetLights reduce bycatch in small-scale fisheries of the eastern Mediterranean. Fish. Res. 272 (April), 106919. https://doi.org/10.1016/j.fishres.2023.106919.

Suazo, Cristián G., Anguita, Cristóbal, Ojeda, Jaime, Luna-Jorquera, Guillermo, Sepúlveda, Maritza, Yates, Oliver, 2024. Ecological experiences and PERCEPTIONS of small-scale gillnet and purse seine fishers on seabirds and other non-target taxa in the HUMBOLDT CURRENT system, CHILE. Mar. Ornithol. 52, 27–36.

Utne-Palm, A.C., Breen, M., Løkkeborg, S., Humborstad, O.-B., 2018. Behavioural responses of krill and cod to artificial light in laboratory experiments. PLoS One 13 (1), e0190918. https://doi.org/10.1371/journal.pone.0190918.

Virgili, M., Petetta, A., Barone, G., Li Veli, D., Bargione, G., Lucchetti, A., 2024. Engaging fishers in sea turtle conservation in the Mediterranean Sea. Mar. Policy 160 (February), 105981. https://doi.org/10.1016/j.marpol.2023.105981.

Virgili, Massimo, Vasapollo, Claudio, Lucchetti, Alessandro, 2018. Can ultraviolet illumination Reduce Sea turtle bycatch in Mediterranean set net fisheries? Fish. Res. 199 (March), 1–7. https://doi.org/10.1016/j.fishres.2017.11.012.

Wang, Jh., Fisler, S., Swimmer, Y., 2010. Developing visual deterrents to reduce sea turtle bycatch in gill net fisheries. Mar. Ecol. Prog. Ser. 408 (June), 241–250. https://doi.org/10.3354/meps08577.

Wang, John, Barkan, Joel, Fisler, Shara, Godinez-reyes, Carlos, Swimmer, Yonat, 2013. Developing ultraviolet illumination of gillnets as a method to Reduce Sea turtle bycatch. Biol. Lett. 9, 20130383.

Whitehead, Darryl, Collin, Shaun, 2004. The functional roles of passive electroreception in non-electric fishes. Anim. Biol. 54 (1), 1–25. https://doi.org/10.1163/157075604323010024.

Worm, Boris, Davis, Brendal, Kettemer, Lisa, et al., 2013. Global catches, exploitation rates, and rebuilding options for sharks. Mar. Policy 40, 194–204. https://doi.org/10.1016/j.marpol.2012.12.034.

Worm, Boris, Orofino, Sara, Burns, Echelle S., et al., 2024. Global shark fishing mortality still rising despite widespread regulatory change. Science 383 (6679), 225–230. https://doi.org/10.1126/science.adf8984.

Yochum, Noëlle, Karlsen, Junita D., Senko, Jesse F., et al., 2024. Guidelines for evaluating artificial light to mitigate unwanted fisheries bycatch. Rev. Fish. Sci. Aquacult. 1–45. https://doi.org/10.1080/23308249.2024.2359417. July 17.

Yu, Mengjie, Changdong Liu, Liyou Zhang, Yanli Tang, 2022. Application of light-emitting diodes (LEDs) fishing lights to improve catch rates of small-scale trammel net fishery in the Yellow Sea, China. Front. Mar. Sci. 9 (November), 1036979. https://doi.org/10.3389/fmars.2022.1036979.

Yu, Mengjie, Herrmann, Bent, Cerbule, Kristine, Liu, Changdong, Zhang, Liyou, Tang, Yanli, 2023. Effect of artificial lights on catch efficiency and capture patterns in Asian paddle crab (Charybdis Japonica) gillnet fishery. Reg. Stud. Mar. Sci. 65 (December), 103101. https://doi.org/10.1016/j.rsma.2023.103101.